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January 6, 1998

Dr. Jay P. Norris
Code 668.1
Laboratory for High Energy Astrophysics
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

Dear Dr. Norris:

This is the final report on CGRO Guest Investigator Program grant NAG5-3514 (PI: Mitchell C. Begelman, The Regents of the University of Colorado, Campus Box 19, Boulder, CO 80309-0019), covering the period 11/15/96–11/14/97. Attached please find a bibliography of the publications to date resulting from this grant.

This grant had as its main goal the reduction and analysis of the archival data for blazars collected (primarily) by the EGRET instrument, interpretation of these data in the context of current theoretical models, and development of new theoretical models for blazar jets.

The first part, the archival data analysis, was done at the GRO Science Support Center (SSC) at Goddard by Mr. Rafal Moderski, a graduate student at the N. Copernicus Astronomical Center working under the co-I Dr. Marek Sikora. He was assisted in this by the SSC support scientists Drs. Darryl Macomb and Chris Shrader. This involved extracting all the blazar data from observations up to and including the GRO Viewing Period 4. This procedure used the standard software, and resulted in a substantial data base which we are currently analyzing. Data processing included extraction of spectra for individual observations of blazars to be used in multi-wavelength fitting, as well as light curves for the analysis of the variability of source fluxes.

The second part, the analysis of those data, is a large, as-yet-uncompleted task, but it has advanced considerably. In particular, we finished the interpretation of the EGRET light curves for blazars. This revealed that in the total sample of observed blazars the intrinsic average distribution of variability amplitudes has a power law shape with $\alpha \sim -0.9$ and shows a marginal indication for a saturation at high amplitudes. We detected, generally, a

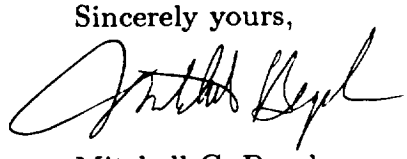
uniform pattern of intrinsic variability with signatures of non-linearity. Similar behavior of variability has been detected previously in samples of radio-sources, but with a much softer distribution of amplitudes $\alpha \sim -4$. The preliminary results were written for publication in the proceedings of Krakow conference on astrophysical jets, and the refereed journal version is now in preparation.

The spectral data extracted by us were used for the construction of overall electromagnetic spectra of a number of sources. These were presented at the Krakow conference as well, by Mr. Blazejowski (a master's degree student of co-I Dr. Sikora); a preprint will be available shortly. An interesting result from this analysis is the measurement of a spectrum of one somewhat unusual blazar, 1622+397 (= 4C 38.41), which shows an extremely luminous "blue bump" in addition to strong GeV emission; in this respect, it is somewhat similar to the well-known 3C273, but with relatively much brighter gamma-ray flux. It is important to stress that these spectral data are of great use in many ongoing and future projects. For instance, they were used in a paper by Kubo et al. (on which co-I Dr. Madejski is a co-author), using the EGRET and Asca data for blazars to constrain possible models for the X-ray emission (ApJ, in press).

Recently, we applied the theoretical methods developed under the auspices of this grant (see below) to the data analysis for BL Lacertae, a blazar recently discovered to flare in the GeV band. This object was initially classified as a BL Lac type object (in fact, the prototype of the class). The overall high energy spectrum of this object — observed during the flare — implies that under the popular scenario where the GeV emission is produced by Comptonization of lower energy photons, in the frame of the jet the external radiation dominates over that of the synchrotron photons internal to the jet. This is actually more typical of quasar-type blazars than BL Lac-type blazars. In this respect, the high energy data shows that "BL Lacertae in not a BL Lac type object", supporting the previous optical discovery of relatively strong emission lines in this object. This result was presented at the High Energy Astrophysics Division meeting in Estes Park by the Co-I Madejski.

The development of theoretical models that resulted from us receiving this grant is perhaps in the most advanced stage. We have written 3 substantial papers (with co-I Dr. Marek Sikora as the lead author). One is a careful comparison of the current theoretical models to the overal spectra of blazars (Sikora et al., ApJ 484, 108), and another deals with the variability observed in blazars (proc. of the Krakow conference). Both develop the currently-popular paradigm that the high energy emission in blazars results from Comptonization of lower energy radiation. The first paper presents a set of tools to determine if the dominant radiation field consists of internal or external photons; it argues for the former for BL Lac-type blazars, and for the latter for quasar-type blazars. The second paper develops the framework for studying flare-type variability of blazars in the context of the external-radiation Compton emission model. Finally, the third paper is reviews the current theoretical models for blazars (in the Proceedings of the 4th Compton Symposium).

Sincerely yours,



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Principal Investigator

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